



Review Article

Gardening is beneficial for health: A meta-analysis

Masashi Soga^{a,*}, Kevin J. Gaston^b, Yuichi Yamaura^c^a Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo, Tokyo 113-8657, Japan^b Environment and Sustainability Institute, University of Exeter, Penryn, Cornwall TR10 9FE, UK^c Forestry and Forest Product Research Institute, Matsunosato 1, Tsukuba, Ibaraki 305-8687, Japan

ARTICLE INFO

Article history:

Received 22 June 2016

Received in revised form 10 October 2016

Accepted 6 November 2016

Available online 14 November 2016

Keywords:

Ecosystem services
 Domestic gardens
 Green exercise
 Green infrastructure
 Horticulture
 Nature experiences
 Preventive healthcare
 Public health
 Urban greenspace
 Wellbeing

ABSTRACT

There is increasing evidence that gardening provides substantial human health benefits. However, no formal statistical assessment has been conducted to test this assertion. Here, we present the results of a meta-analysis of research examining the effects of gardening, including horticultural therapy, on health. We performed a literature search to collect studies that compared health outcomes in control (before participating in gardening or non-gardeners) and treatment groups (after participating in gardening or gardeners) in January 2016. The mean difference in health outcomes between the two groups was calculated for each study, and then the weighted effect size determined both across all and sets of subgroup studies. Twenty-two case studies (published after 2001) were included in the meta-analysis, which comprised 76 comparisons between control and treatment groups. Most studies came from the United States, followed by Europe, Asia, and the Middle East. Studies reported a wide range of health outcomes, such as reductions in depression, anxiety, and body mass index, as well as increases in life satisfaction, quality of life, and sense of community. Meta-analytic estimates showed a significant positive effect of gardening on the health outcomes both for all and sets of subgroup studies, whilst effect sizes differed among eight subgroups. Although Egger's test indicated the presence of publication bias, significant positive effects of gardening remained after adjusting for this using trim and fill analysis. This study has provided robust evidence for the positive effects of gardening on health. A regular dose of gardening can improve public health.

© 2016 Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Contents

1.	Introduction	93
2.	Materials and methods	93
	2.1. Terminology	93
	2.2. Systematic review and inclusion criteria	93
	2.3. Data extraction	94
	2.4. Statistical analysis	94
	2.5. Publication bias	95
3.	Results	95
	3.1. Descriptive results	95
	3.2. Meta-analysis results	95
	3.3. Publication bias	96
4.	Discussion	96
5.	Conclusions	98
	Acknowledgments	98
	References	98

* Corresponding author.

E-mail address: masashi.soga.mail@gmail.com (M. Soga).

1. Introduction

Globally, the prevalence of the so-called “lifestyle diseases,” such as heart disease, stroke, depression, diabetes, and obesity is becoming a major public health issue (Caballero, 2007; Janssen et al., 2005; Moussavi et al., 2007). It is, for example, estimated that worldwide, approximately 415 and 350 million people presently suffer from diabetes and depression, respectively, and hence both are costly to national health care budgets (IDF, 2015; WHO, 2016). Unfortunately, this trend is expected to continue for the foreseeable future as a high number and proportion of the world’s population will be living in urban areas (Seto et al., 2012). Indeed, urban living is associated with various adverse health consequences, such as high-fat diets, sedentary lifestyles, and increased levels of social and psychological stress and environmental pollutants (Clougherty et al., 2007; Lambert et al., 2015; Peer et al., 2003; Sodjinou et al., 2008). As a consequence, promoting health of urban populations has become one of the most challenging issues of the 21st century (Dye, 2008; Tzoulas et al., 2007).

Nature in cities can play a key role in achieving a healthy society (Groenewegen et al., 2006; Tzoulas et al., 2007). Indeed, there is mounting evidence that direct experience with natural environments offers a wide range of health benefits (Hartig et al., 2014; Keniger et al., 2013; Soga and Gaston, 2016). Louv (2005) argued that a decrease in contact with nature results in a number of health and behavioural problems, especially for children, which in sum can constitute a “nature-deficit disorder.” Recent studies suggest that daily contact with nature has a long-lasting and deep impact on health, including on depression and anxiety symptoms (Beyer et al., 2014), birth weight (Dadvand et al., 2012), diabetes, and obesity (Lachowycz and Jones, 2011), circulatory and heart disease (Maas et al., 2009), and longevity (Takano et al., 2002). It is therefore increasingly recognized that a regular contact with nature can promote human health and be used as a form of preventive medicine (Groenewegen et al., 2006).

Gardening is arguably one of the most common ways of interacting with nature and indeed is enjoyed as a popular pastime in many countries. In the UK, there are estimated to be 27 million people, approximately 40% of the total population, who actively participate in gardening (Bisgrove and Hadley, 2002). Likewise, it is estimated that in the US, 117 million people, one in three, participate in gardening (Statista, 2015), and that in Japan, 32 million people, one in four, participate in daily gardening as a hobby (Statistics Bureau, Ministry of Internal Affairs and Communications, 2011). Gardening requires, at most, a relatively small piece of land, and in many parts of the world, such gardens are today common. In the UK, it is estimated that 22.7 million households (87%) have access to a domestic garden, which comprise 432,924 ha of land in total (Davies et al., 2009). Mathieu et al. (2007) also showed that more than a third of the land in the city of Dunedin, New Zealand, was used for domestic gardens. Alongside domestic gardens, allotment and community gardens, pieces of land with plots rented by an individual or group to grow plants for non-commercial use also offer places in which people can participate in gardening. The city of Stockholm, Sweden, for example, contains approximately 10,000 allotment plots, which occupy 210 ha of land and involve 24,000 people (c.f. Barthel et al., 2010). Given the scale of gardening activities, and the apparent feasibility of accommodating them in cities and towns, these have great potential for limiting the ongoing loss of human–nature interaction—the extinction of experience (Soga and Gaston, 2016; Soga et al., 2016).

There is increasing awareness among researchers and health practitioners of the potential health benefits derived from gardening activities (Clatworthy et al., 2013; Genter et al., 2015; Wang and MacMillan, 2013). Indeed, previous studies have shown that gardening increases individual’s life satisfaction, vigor, psychological wellbeing, positive affects, sense of community, and cognitive function (Gigliotti and Jarrott, 2005; Gonzalez et al., 2010; van den Berg et al., 2010; Wakefield et al., 2007; Wichrowski et al., 2005; Wood et al., 2016).

Reductions in stress, anger, fatigue, and depression and anxiety symptoms have also been documented (Rodiek, 2002; Wichrowski et al., 2005; Wilson and Christensen, 2011; Wood et al., 2016). In consequence, engagement with gardening has increasingly been recognized as not only a cost-effective health intervention (Clatworthy et al., 2013) but also a treatment or occupational therapy for those with psychological health issues, so-called “horticultural therapy” (Gonzalez et al., 2010, 2011a). Despite this, surprisingly, to date no meta-analysis has been conducted to assess the consistency of the positive effects of gardening on health. There have recently been two systematic reviews of studies exploring the association between gardening and health (Genter et al., 2015; Wang and MacMillan, 2013). However, since they presented no quantitative synthesis and only focused on health benefits of allotment gardening (Wang and MacMillan, 2013) and for elderly people (Genter et al., 2015), respectively, more comprehensive and convincing evidence is still wanting. Here, we present a formal meta-analysis of research examining the effects of gardening on health.

2. Materials and methods

2.1. Terminology

As defined by the WHO (1948), health is “a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity,” we interpret “health” in a broad sense to include physical and psychological wellbeing. Positive effects on health are thus not simply the amelioration of symptoms associated with chronic illness (e.g. depression, anxiety, obesity) but include the presence of positive emotions (e.g. quality of life, life satisfaction, sense of community, happiness) and the absence of negative emotions (e.g. anger, loneliness, confusion), and the state of being able to perform the normal actions of daily life without the hindrance of both physical and psychological dysfunction. Increased physical activity level was also included as a positive health outcome, as it has proven to be a good indicator of risk for obesity-related diseases (Janssen et al., 2005). We use the term “gardening” for “an activity in which people grow, cultivate, and take care of plants (flowers and vegetables) for non-commercial use,” which is not simply limited to an activity in domestic gardens but includes that in allotment and community gardens. In this study, horticultural therapy, a practice of engaging patients in gardening activities to improve their physical, psychological, and social health, was also considered as a form of gardening.

2.2. Systematic review and inclusion criteria

We focused on studies that collected data on people’s health outcomes in the context of gardening, were published in peer-reviewed scientific journals after 2001, and were written in English. This study followed the PRISMA statement (Moher et al., 2009). We performed the search, assessed eligibility, and extracted data. Literature search was conducted using the PubMed database in January 2016. We used the following terms in the keyword search: *Physical activity* OR *Health* OR *Restoration* OR *Recovery* OR *Therapy* OR *Well-being* OR *Wellbeing* OR *Well being* OR *Psychology* OR *Quality of life* OR *Life satisfaction* OR *Happiness* OR *Anxiety* OR *Depression* OR *Stress* OR *mood* OR *Pain* OR *Obesity* OR *Social* AND *Gardening* OR *Allotment* OR *Allotment gardening* OR *Horticulture* OR *Horticultural therapy* OR *Community Garden*. The PubMed search resulted in 2456 records. We also ran similar queries on Google Scholar in January 2016 to identify studies that had previously been missed. We searched using all possible combinations of the above 19 health terms and 6 gardening terms (114 combinations), and examined the first 50 hits from each (5700 records in total). Studies identified through PubMed and Google Scholar were screened on title, abstract, or both, and 79 full-articles were assessed for eligibility. The eligible articles were obtained from the Internet, via the University of Tokyo electronic library, or by personal contact with the authors. To be included in

our meta-analysis, a study had to (1) conduct a quantitative survey rather than a qualitative one, (2) focus on outdoor gardening, (3) have control (before participating in gardening or non-gardeners) and treatment groups (after participating in gardening or gardeners), (4) report sample size and mean and standard deviation (SD) or error (SE) of health outcomes both for the control and treatment groups, and (5) have >11 participants (sample size). Reviews of previous work and study protocols were ignored.

2.3. Data extraction

We finally included 21 articles [22 case studies; one paper (Gonzalez et al., 2011a) reported two independent studies] in the meta-analysis (see Table 1). The study selection process (PRISMA diagram) is shown in Fig. 1. Basic information was collected for these studies, including the first author's name, year and name of publication, country of origin, and details of settings (duration and types of gardening), participants (mean age, female ratio, and health condition), and types of health outcomes measured. We also extracted mean values of health outcomes, sample size (n), and SD for both the control and treatment groups. If a single study reported data on more than one health outcome, then we considered each comparison between the control and treatment groups (hereafter comparison) independently. Duplicate results that were derived from repeated analyses (e.g. subgroup analysis) were ignored. For studies that measured health outcomes during gardening on multiple occasions, we used only data points at the start (control) and end (treatment). One study (Park et al., 2009) compared health outcomes of people with multiple levels of gardening activity (non-gardeners, gardeners, and active gardeners; here, active gardeners were defined

as those who met or exceeded recommended physical activity levels by gardening, and gardeners as those who did not meet this recommendation by gardening but did garden as moderate intensity). In this case, we compared only non-gardeners and gardeners. We finally obtained 76 comparisons. The full dataset is listed in Table S1.

2.4. Statistical analysis

We performed the meta-analysis using the “metafor” package (Viechtbauer, 2010) in R (ver. 3.2.2) (R Core Team, 2015). The standardized mean difference Hedges' d (Hedges and Olkin, 1985) was used as the effect size metric for comparing mean differences in health outcomes between the treatment and control groups:

$$d = (M_t - M_c) / S$$

where M_t and M_c are the mean values of the response variable (health outcomes) in the treatment and control groups, respectively, and S and J are the pooled SD of both groups and a term that corrects for bias due to small sample size, respectively. Here, positive effect sizes indicate that health condition is better in the treatment groups than in the control groups; we reversed the sign of health outcomes where higher values meant a less healthy condition (e.g. depression, anxiety, stress).

Based on the effect size of each comparison, we calculated the overall pooled effect size and its 95% confidence interval (CI) as a weighted average of all 22 case studies (76 comparisons). Significance of the overall effect size was assessed by determining whether the CI overlapped zero. Since preliminary analysis showed significant between-study heterogeneity (see the Results section), we used a weighted random-

Table 1
Characteristics of 22 case studies.

Study	Country	Participants	% Female	Mean age	Gardening type	Health outcome
Ghanbari et al. (2015)	Iran	50 female students with depression	100.0	20.6	Horticultural therapy	Depression
Gigliotti and Jarrott (2005)	USA	48 people with dementia	45.8	80.0	Horticultural therapy	Positive affect
Gigliotti et al. (2004)	USA	14 people with dementia	–	83.0	Horticultural therapy	Positive affect
Gonzalez et al. (2010)	Norway	28 people with depression	75.0	44.1	Horticultural therapy	Depression, attention (cognitive function), brooding (rumination), and being away and fascination (restorativeness)
Gonzalez et al. (2011a)	Norway	18 people with depression	83.3	49.7	Horticultural therapy	Depression and existential issues
Gonzalez et al. (2011a)	Norway	28 people with depression	75.0	44.1	Horticultural therapy	Depression and existential issues
Gonzalez et al. (2011b)	Norway	46 people with depression	78.3	46.3	Horticultural therapy	Depression, anxiety, positive affect, and stress
Hayashi et al. (2008)	Japan	61 people	63.9	46	Experimental short-term gardening	Mood, tension, depression, anger, vigor, fatigue, and confusion
Kam and Siu (2010)	China	24 people with psychological illness	29.2	44.3	Horticultural therapy	Depression, anxiety, stress, and quality of life
Kim et al. (2012)	South Korea	24 students with intellectual disabilities	58.3	8.5	Horticultural therapy	Attention (cognitive function) and sociability
Kotozaki (2014)	Japan	45 women	100.0	46.5	Horticultural therapy	Sense of community, self-esteem, general health, and depression
Min et al. (2014)	South Korea	45 women	100.0	–	Horticultural therapy	Psychological wellbeing and hope
Park et al. (2009)	USA	53 people	64.2	71.9	Daily gardening	Bone mineral density
Rodiek (2002)	USA	17 women	100.0	84.7	Experimental short-term gardening	Anxiety, mood, and salivary cortisol (stress)
Sommerfeld et al. (2010)	USA	261 people	59.8	over 50	Daily gardening	Life satisfaction, physical activity levels, and general health
van den Berg and Custers (2011)	Netherlands	30 people	73.3	57.6	Experimental short-term gardening	Mood and salivary cortisol (stress)
van den Berg et al. (2010)	Netherlands	184 people	51.1	59.6	Daily gardening	General health, physical constraints, health complaints, chronic illnesses, frequency of consulting in general practice, stress, life satisfaction, loneliness, social contacts, physical activity levels
Waliczek et al. (2005)	USA	443 people	72.8	–	Daily gardening	Life satisfaction
Wichrowski et al. (2005)	USA	107 cardiac rehabilitation inpatients	39.3	–	Horticultural therapy	Mood, tension, depression, anger, vigor, fatigue, confusion, and heart rate (stress)
Wilson and Christensen (2011)	USA	269 people with disabilities	62.1	55	Daily gardening	Depression
Wood et al. (2016)	UK	269 people	43.5	55.6	Daily gardening	Self-esteem, general health, tension, depression, anger, vigor, fatigue, confusion, mood, and body mass index
Zick et al. (2013)	USA	514 people	49.8	43.9	Daily gardening	Body mass index

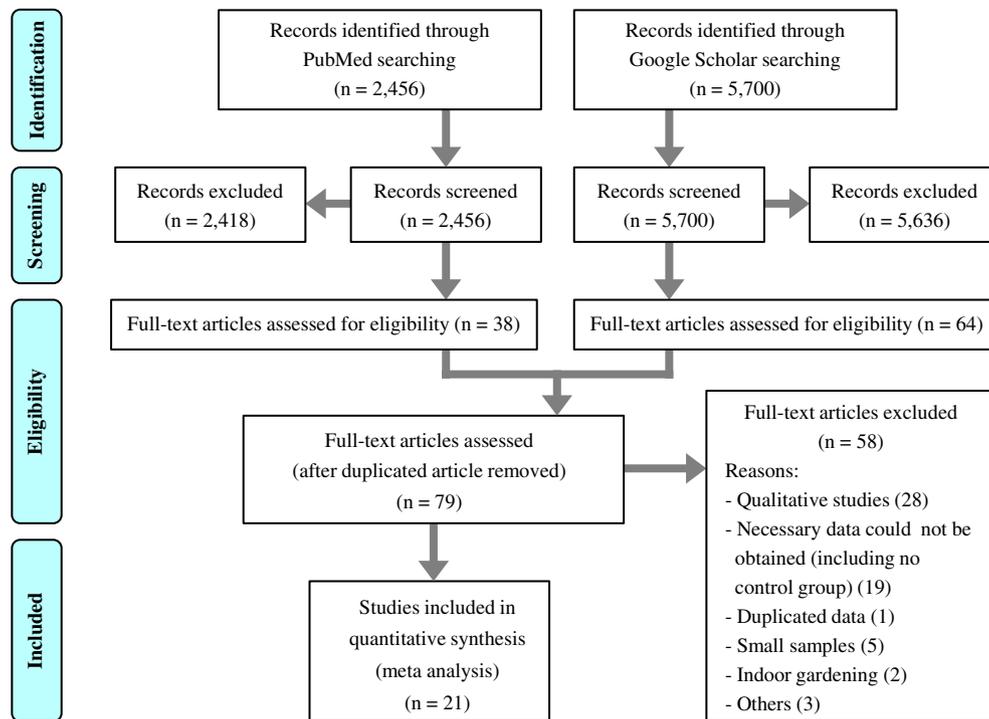


Fig. 1. Flow diagram of literature search and study selection process.

effects model to estimate the overall effect size and CI. The random-effects model assumes that different studies are not exactly identical in the survey methodologies and the characteristics of respondents. Heterogeneity between studies was checked by the Q test and I^2 statistic. In order to account for the possibility of pseudoreplication derived from using multiple comparisons from within studies, we recalculated the overall effect sizes after sampling one comparison from each separate study. The estimated mean and 95% CI of effect size were computed by bootstrap resampling 10,000 times in R.

As well as for the overall studies ($n = 76$ comparisons), a meta-analysis was performed for different groups of studies (hereafter subgroups) to examine whether the impacts of gardening on health differed. We split the 76 comparisons into two subgroups based on the types of health outcomes (health variables: $n = 18$; wellbeing variables: $n = 58$), gardening (therapy: $n = 33$; non-therapy: $n = 43$), comparisons (before/after gardening: $n = 32$; gardeners/non-gardeners: $n = 44$), and respondents (patients: $n = 28$; non-patients: $n = 48$). In this study, “wellbeing” was interpreted simply as “the state of being comfortable, happy, or prosperous”; proposing a single definition of wellbeing is still a substantial general challenge (Dodge et al., 2012). This includes the presence of positive emotions (e.g. happiness, vigor, hope), the absence of negative emotions (e.g. loneliness, anger, confusion), and satisfaction and fulfillment of life. Statistical difference in the mean effect size between two subgroups in each category was evaluated with Cochran's Q test implemented in the “metafor” package in R.

2.5. Publication bias

The possibility of publication bias (a lower likelihood of studies being published that reported non-significant results than reported significant ones) was assessed using a funnel plot and Egger's test (Egger et al., 1997; Nakagawa and Santos, 2012). If publication bias was indicated by Egger's test, we performed a trim and fill analysis (with the R0 estimator) (Duval and Tweedie, 2000). This estimates the number of missing studies (comparisons) in the original dataset and provides a true effect size: that is, an effect size when publication bias is not present.

The trim and fill analysis was performed using the “trimfill” functions of the “metafor” package in R.

3. Results

3.1. Descriptive results

An overview of the 22 case studies is presented in Table 1. The sample sizes ranged from 14 to 514 people ($M = 117.2$, $SD = 144.5$). Many of the studies came from the United States (9 studies), followed by Europe (7 studies), Asia (5 studies), and the Middle East (1 study). The participants ranged in average age from 8.5 to 84.7 years ($M = 52.3$, $SD = 19.6$), with the percentage of females ranging from 29.2 to 100.0% ($M = 67.8$, $SD = 21.0$). Eleven studies focused on patients (e.g. dementia, depression) and 11 on non-patients. Gardening types included horticultural therapy (12 studies), daily gardening (7 studies), and experimental short-term gardening (3 studies). Studies used a wide range of health outcomes (Table 1).

3.2. Meta-analysis results

The results of the 76 comparisons and the meta-analytic estimates are shown in Fig. 2. Most studies reported positive effects of gardening, and none reported significant negative effects (Fig. 2). The 95% CI of the overall pooled effect size did not overlap zero (mean = 0.42, 95% CI: 0.36–0.48), suggesting a significant effect of gardening on the health outcomes (Fig. 2). We found significant between-study heterogeneity in the overall analysis ($I^2 = 40.47%$, $Q_{75} = 137.38$, $P < 0.001$). After repeated resampling using bootstrap simulation, the overall effect sizes remained significantly positive (mean = 0.47, 95% CI: 0.36–0.57) and its 95% CIs largely overlapped with those in the primary analysis (Fig. S1). Thus, the reported results overall would not be biased by pseudoreplication.

The 95% CI of effect size did not overlap zero for all eight subgroups (Table 2). The effect size of gardening on the health outcomes differed significantly between two subgroups for all four categories (outcome types: $Q_1 = 6.48$, $P = 0.01$; gardening types: $Q_1 = 24.71$, $P < 0.001$;

comparison types: $Q_1 = 18.31, P < 0.001$; respondent types: $Q_1 = 17.96, P < 0.001$ (Table 2). Studies focused on wellbeing variables, horticultural therapy, before/after comparison method, and patients showed higher effect sizes of gardening, compared to the other subgroups (Table 2). Of the eight subgroups, between-study heterogeneity was found for five (Table 2).

3.3. Publication bias

Egger's test indicated the presence of publication bias ($t = 4.18, d.f. = 64, P < 0.001$). The trim and fill analysis suggested that 16 studies (comparisons) were missing from our dataset (white circles in Fig. 3). However, after adding those missing data to the original dataset,

reported significant effects of gardening on the health outcomes were intact (mean = 0.35; 95% CI: 0.27–0.43, Fig. 3), suggesting that the effects of publication bias on the overall results were negligible.

4. Discussion

To our knowledge, this meta-analysis is the first to provide a quantitative synthesis of the evidence that gardening is beneficial for human health. Overall, the results suggest that participating in gardening activities has a significant positive impact on health. Indeed, the positive association with gardening was observed for a wide range of health outcomes, such as reductions in depression and anxiety symptoms, stress, mood disturbance, and BMI, as well as increases in quality of

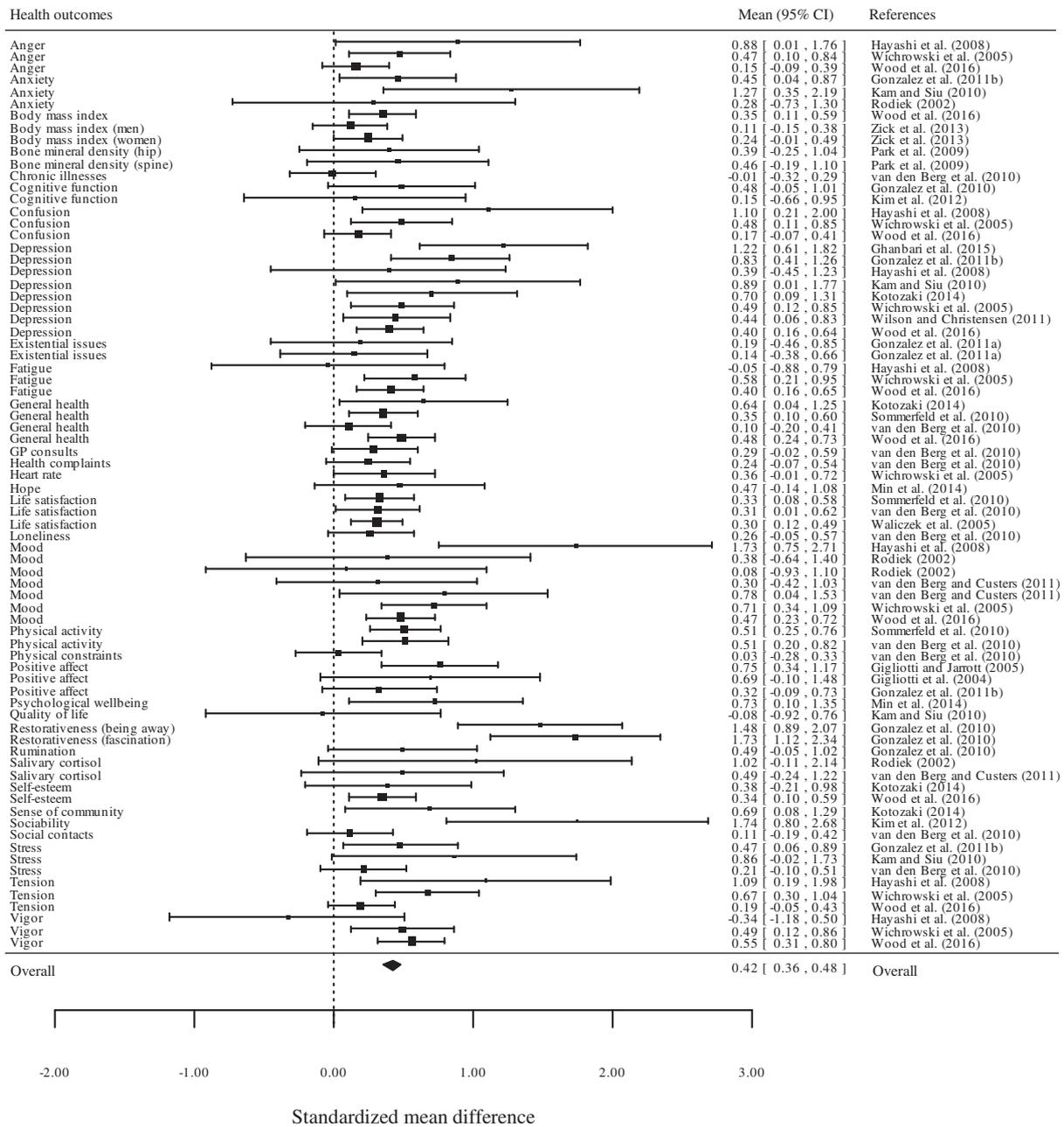


Fig. 2. Standardized mean differences in the health outcomes between the control and treatment groups for 76 comparisons. Positive values indicate improved health outcomes. Dotted and solid lines indicate the effect size of 0 and 95% CI, respectively. Positive affect means the extent to which one is experiencing positive mood states, such as joy, cheerfulness, and enthusiasm.

life, sense of community, physical activity levels, and cognitive function. The 22 case studies were geographically dispersed, although more than one-third came from the United States. Publication bias is a common limitation of meta-analysis (Nakagawa and Santos, 2012). Nevertheless, our results remained quantitatively almost unchanged after using the trim and fill analysis, suggesting that the reported health benefits of gardening are robust. Given the recent rise in awareness of the health benefits derived from nature (Hartig et al., 2014; Keniger et al., 2013), these findings are particularly timely and support the argument that a regular dose of gardening can improve health.

Studies included in our analysis varied substantially with respect to the demographic characteristics of the participants and settings, which is likely to be the main reason for significant between-study heterogeneity. To account for this issue, we performed subgroup analysis and determined that significant positive effects of gardening on health existed for all subgroups. Positive influences of gardening were particularly evident on patients and horticultural therapy users. This is unsurprising because these groups would explicitly use, and be exposed to, gardens in a more health-supportive way than would non-patients. Likewise, studies using a “before and after” comparison method, which were commonly seen in horticultural therapy studies (Ghanbari et al., 2015; Gonzalez et al., 2010, 2011a, 2011b; Kotozaki, 2014; Min et al., 2014; Wichrowski et al., 2005), reported a larger effect size of gardening than those simply comparing a treatment (gardeners) to a control group (non-gardeners). Our subgroup analysis also indicated that wellbeing variables are more likely enhanced sharply by gardening than health variables. Although it is difficult to provide a precise explanation due to the limited sample size, one possible reason for this result is that the improvement of health variables would need a relatively longer time, compared to wellbeing. As wellbeing variables were in many cases measured on a subjective scale (e.g. depression, anxiety, quality of life, life satisfaction) (Ghanbari et al., 2015; Kam and Siu, 2010; Kotozaki, 2014; van den Berg et al., 2010; Waliczek et al., 2005; Wood et al., 2016), they were more likely to respond immediately than objective health outcomes (e.g. BMI) (Park et al., 2009; van den Berg et al., 2010; Wood et al., 2016; Zick et al., 2013).

There was substantial variation among the 22 case studies in the duration and frequency of the gardening treatment, and each study has its particular implications. Three studies assessed respondents shortly before and after experimental short-term gardening activities (Hayashi et al., 2008; Rodiek, 2002; van den Berg and Custers, 2011). These studies showed that even short-time (several hours) exercise in gardens can provide an instantaneous beneficial influence on health (e.g. reductions in depression and anxiety symptoms), although it is unknown how long the positive outcomes last after gardening. Twelve studies focused on horticultural therapy and investigated changes in people's health states over several weeks or months (Ghanbari et al., 2015; Gigliotti and

Jarrott, 2005; Gigliotti et al., 2004; Gonzalez et al., 2010, 2011a, 2011b; Kam and Siu, 2010; Kim et al., 2012; Kotozaki, 2014; Min et al., 2014; Wichrowski et al., 2005). Notably, Gonzalez et al. (2010, 2011a, 2011b) observed that improvement of patients' health states (e.g. depression severity, life satisfaction, cognitive function) persisted at 3-months' follow up after the therapy, indicating that gardening has a persisting influence on health. Of the 22 case studies, 7 studies focused on daily gardening and found that those who participated had better health than did non-gardeners, such as reductions in stress and BMI, as well as increases in general health and life satisfaction (Park et al., 2009; Sommerfeld et al., 2010; van den Berg et al., 2010; Waliczek et al., 2005; Wilson and Christensen, 2011; Wood et al., 2016; Zick et al., 2013). The strength of these studies is that they found no significant difference in the characteristics or socio-economic status of gardeners and non-gardeners, or controlled for these factors. Also, these studies indicate that repeated short-term exercise in gardens has a cumulative effect on health. Given the evidence presented above, it is obvious that gardening has both immediate and long-term effects on health, and an important direction for future research is to determine the shape of relationships between the dose (duration and frequency) of gardening exercise and health outcomes.

Although our meta-analysis presents a consistent result, untangling the causal relationships between gardening and improved health outcomes is not an easy task. There are several possible, but not mutually exclusive, pathways through which gardening promotes health. The first, and most direct one, is the added health benefits of direct experience with nature (Hartig et al., 2014; Keniger et al., 2013). Indeed, attention restoration theory proposes that the natural world is cognitively restorative and exposure to nature has the potential to allow restoration from attention fatigue (Kaplan, 1995). Second, and somewhat more indirectly, gardening is likely to encourage people to undertake physical exercise, which in turn would contribute to improving both the physical and psychological health of gardeners (Park et al., 2009; van den Berg et al., 2010; Zick et al., 2013). Notably, in the US, Park et al. (2008) pointed out that if elderly people participated in daily gardening, they could achieve recommended physical activity levels (at least 30 min of moderate intensity physical activity on most, preferably all, days). Third, gardens, especially allotment and community gardens, provide opportunities to interact with other members of local communities, which is likely to forge and reinforce social ties, community networks, and sense of community (van den Berg et al., 2010; Wakefield et al., 2007). Fourth, and most indirectly, engagement in gardening could ensure people have a healthier diet, rich in fruits and vegetables (Langellotto and Gupta, 2012). Given these widespread benefits coming from gardening, we should consider gardens as an important and promising health resource for the local community.

Table 2
Summary of the meta-analysis for eight subgroups.

Subgroups	No. of comparison	Effect size			Heterogeneity	Between-subgroup difference
		Mean	SE	95% CI		
<i>Outcome types</i>						
Health variables	18	0.31	0.05	0.21–0.40	$Q_{17} = 28.93, P = 0.04$ $Q_{57} = 102.53,$ $P < 0.001$	$Q_1 = 6.48, P = 0.01$
Wellbeing variables	58	0.47	0.04	0.39–0.54		
<i>Gardening types</i>						
Therapy	33	0.61	0.05	0.51–0.72	$Q_{32} = 51.76, P = 0.02$ $Q_{42} = 53.85, P = 0.10$	$Q_1 = 24.71, P < 0.001$
Non-therapy	43	0.31	0.03	0.26–0.37		
<i>Comparison types</i>						
Before/after gardening	32	0.60	0.06	0.49–0.71	$Q_{31} = 54.03,$ $P = 0.006$ $Q_{43} = 57.51, P = 0.07$	$Q_1 = 18.31, P < 0.001$
Gardeners/non-gardeners	44	0.32	0.03	0.27–0.38		
<i>Participant types</i>						
Patients	28	0.61	0.06	0.49–0.74	$Q_{27} = 51.30,$ $P = 0.003$ $Q_{47} = 59.37, P = 0.11$	$Q_1 = 17.96, P < 0.001$
Non-patients	48	0.32	0.03	0.27–0.38		

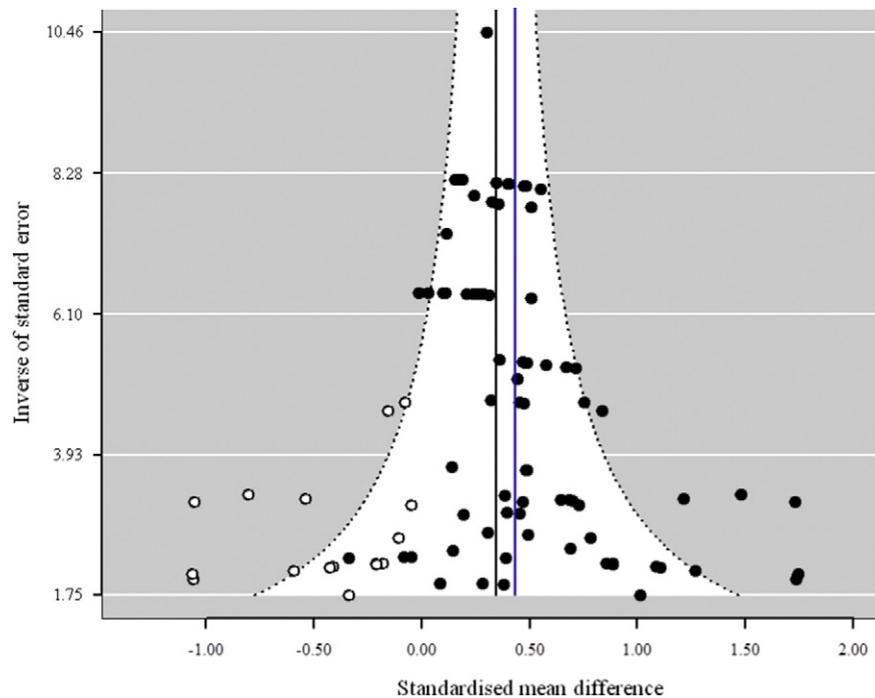


Fig. 3. A funnel plot to assess potential publication bias. Measures of effect size (standardized mean differences) and study precision (the inverse of standard error) are shown on the x- and y-axes, respectively. The filled and open circles represent observed data (76 comparisons) and data added (16 studies) by the trim-and-fill analysis (see the main text). Blue and black centerlines indicate the meta-analytical mean before (see Fig. 2) and after adding these 16 data points to the original 76 (i.e. adjusted effect size).

5. Conclusions

Our meta-analysis has provided robust evidence for the positive effects of gardening on health. With an increasing demand for reduction of health care costs worldwide, our findings have important policy implications. The results presented here suggest that gardening can improve physical, psychological, and social health, which can, from a long-term perspective, alleviate and prevent various health issues facing today's society. We therefore suggest that government and health organizations should consider gardening as a beneficial health intervention and encourage people to participate in regular exercise in gardens. To do so, policy makers need to increase people's opportunity and motivation to engage with gardening activities. The former requires enough spaces where people can enjoy gardening, and the latter needs the various advantages of gardening to be made apparent to a broad audience. Because gardens are accessible spaces for all kinds of people, including children, elderly people, and those with a disability, and relatively easily and quickly implemented in urban areas as a "land-sharing" strategy (Soga et al., 2015; Stott et al., 2015), we believe that such actions and policies would at the same time contribute greatly to redressing health inequalities.

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.pmedr.2016.11.007>.

Acknowledgments

MS was supported by the Japan Society of Promotion of Science (grant number 16K00631). KJG was supported by the Natural Environment Research Council (grant number NE/J015237/1). YY was supported by JSPS KAKENHI (grant number 26292074).

References

Barthel, S., Folke, C., Colding, J., 2010. Social-ecological memory in urban gardens—retaining the capacity for management of ecosystem services. *Glob. Environ. Chang.* 20, 255–265.

Beyer, K.M., Kaltenbach, A., Szabo, A., Bogar, S., Nieto, F.J., Maleczi, K.M., 2014. Exposure to neighborhood green space and mental health: evidence from the survey of the health of Wisconsin. *Int. J. Environ. Res. Public Health* 11, 3453–3472.

Bisgrove, R., Hadley, P., 2002. Gardening in the Global Greenhouse: The Impacts of Climate Change on Gardens in the UK. UK Climate Impacts Programme, Oxford, UK.

Caballero, B., 2007. The global epidemic of obesity: an overview. *Epidemiol. Rev.* 29, 1–5.

Clatworthy, J., Hinds, J.M., Camic, P., 2013. Gardening as a mental health intervention: a review. *Ment. Health Rev. J.* 18, 214–225.

Clougherty, J.E., Levy, J.L., Kubzansky, L.D., et al., 2007. Synergistic effects of traffic-related air pollution and exposure to violence on urban asthma etiology. *Environ. Health Perspect.* 115, 1140–1146.

Dadvand, P., de Nazelle, A., Figueras, F., et al., 2012. Green space, health inequality and pregnancy. *Environ. Int.* 40, 110–115.

Davies, Z.G., Fuller, R.A., Loram, A., Irvine, K.N., Sims, V., Gaston, K.J., 2009. A national scale inventory of resource provision for biodiversity within domestic gardens. *Biol. Conserv.* 142, 761–771.

Dodge, R., Daly, A.P., Huyton, J., Sanders, L.D., 2012. The challenge of defining wellbeing. *Int. J. Wellbeing* 2, 222–235.

Duval, S., Tweedie, R., 2000. A nonparametric "trim and fill" method of accounting for publication bias in meta-analysis. *J. Am. Stat. Assoc.* 95, 89–98.

Dye, C., 2008. Health and urban living. *Science* 319, 766–769.

Egger, M., Smith, G.D., Schneider, M., Minder, C., 1997. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 315, 629–634.

Genter, C., Roberts, A., Richardson, J., Sheaff, M., 2015. The contribution of allotment gardening to health and wellbeing: a systematic review of the literature. *Br. J. Occup. Ther.* 78, 593–605.

Ghanbari, S., Jafari, F., Bagheri, N., Neamtollahi, S., Shayanpour, R., 2015. Study of the effect of using purposeful activity (gardening) on depression of female resident in Golestan Dormitory of Ahvaz Jundishapur University of Medical Sciences. *J. Rehabil. Sci. Res.* 2, 8–11.

Gigliotti, C.M., Jarrott, S.E., 2005. Effects of horticulture therapy on engagement and affect. *Can. J. Aging* 24, 367–377.

Gigliotti, C.M., Jarrott, S.E., Yorgason, J., 2004. Harvesting health effects of three types of horticultural therapy activities for persons with dementia. *Dementia* 3, 161–180.

Gonzalez, M.T., Hartig, T., Patil, G.G., Martinsen, E.W., Kirkevel, M., 2010. Therapeutic horticulture in clinical depression: a prospective study of active components. *J. Adv. Nurs.* 66, 2002–2013.

Gonzalez, M.T., Hartig, T., Patil, G.G., Martinsen, E.W., Kirkevel, M., 2011a. A prospective study of existential issues in therapeutic horticulture for clinical depression. *Issues Ment. Health Nurs.* 32, 73–81.

Gonzalez, M.T., Hartig, T., Patil, G.G., Martinsen, E.W., Kirkevel, M., 2011b. A prospective study of group cohesiveness in therapeutic horticulture for clinical depression. *Int. J. Ment. Health Nurs.* 20, 119–129.

Groenewegen, P.P., van den Berg, A.E., de Vries, S., Verheij, R.A., 2006. Vitamin G: effects of green space on health, well-being, and social safety. *BMC Public Health* 6, 149.

Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. *Annu. Rev. Public Health* 35, 207–228.

Hayashi, N., Wada, T., Hirai, H., et al., 2008. The effects of horticultural activity in a community garden on mood changes. *Environ. Control. Biol.* 46, 233–240.

Hedges, L., Olkin, I., 1985. *Statistical Models for Meta-Analysis*. Academic Press, New York.

International Diabetes Federation (IDF), 2015. *Diabetes Atlas*, seventh ed. (Brussels, Belgium).

- Janssen, I., Katzmarzyk, P.T., Boyce, W.F., et al., 2005. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes. Rev.* 6, 123–132.
- Kam, M.C., Siu, A.M., 2010. Evaluation of a horticultural activity programme for persons with psychiatric illness. *Hong Kong J. Occup. Ther.* 20, 80–86.
- Kaplan, S., 1995. The restorative benefits of nature: toward an integrative framework. *J. Environ. Psychol.* 15, 169–182.
- Keniger, L.E., Gaston, K.J., Irvine, K.N., Fuller, R.A., 2013. What are the benefits of interacting with nature? *Int. J. Environ. Res. Public Health* 10, 913–935.
- Kim, B.Y., Park, S.A., Song, J.E., Son, K.C., 2012. Horticultural therapy program for the improvement of attention and sociality in children with intellectual disabilities. *HortTechnology* 22, 320–324.
- Kotozaki, Y., 2014. Horticultural therapy as a measure for recovery support of regional community in the disaster area: a preliminary experiment for forty five women who living certain region in the coastal area of Miyagi Prefecture. *Int. J. Emerg. Ment. Health* 16, 114–116.
- Lachowycz, K., Jones, A.P., 2011. Greenspace and obesity: a systematic review of the evidence. *Obes. Rev.* 12, e183–e189.
- Lambert, K.G., Nelson, R.J., Jovanovic, T., Cerdá, M., 2015. Brains in the city: neurobiological effects of urbanization. *Neurosci. Biobehav. Rev.* 58, 107–122.
- Langellotto, G.A., Gupta, A., 2012. Gardening increases vegetable consumption in school-aged children: a meta-analytical synthesis. *HortTechnology* 22, 430–445.
- Louv, R., 2005. *Last child in the woods: saving out children from nature-deficit disorder*. Algonquin Books of Chapel Hill, Chapel Hill, NC, USA.
- Maas, J., Verheij, R.A., de Vries, S., Spreeuwenberg, P., Schellevis, F.G., Groenewegen, P.P., 2009. Morbidity is related to a green living environment. *J. Epidemiol. Community Health* 63, 967–973.
- Mathieu, R., Freeman, C., Aryal, J., 2007. Mapping private gardens in urban areas using object-oriented techniques and very high-resolution satellite imagery. *Landsc. Urban Plan.* 81, 179–192.
- Min, S., Ha, Y.J., Kang, J.H., Kang, H.Y., 2014. The effects of horticultural therapy on the well-being and hope of women in rural Korea. *J. Nurs. Care* 3, 2167–1168.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., The PRISMA Group, 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 151, 264–269.
- Moussavi, S., Chatterji, S., Verdes, E., Tandon, A., Patel, V., Ustun, B., 2007. Depression, chronic diseases, and decrements in health: results from the World Health Surveys. *Lancet* 370, 851–858.
- Nakagawa, S., Santos, E.S., 2012. Methodological issues and advances in biological meta-analysis. *Evol. Ecol.* 26, 1253–1274.
- Park, S.A., Shoemaker, C., Haub, M., 2008. Can older gardeners meet the physical activity recommendation through gardening? *HortTechnology* 18, 639–643.
- Park, S.A., Shoemaker, C.A., Haub, M.D., 2009. Physical and psychological health conditions of older adults classified as gardeners or nongardeners. *Hortscience* 44, 206–210.
- Peer, N., Bradshaw, D., Laubscher, R., Steyn, N., Steyn, K., 2003. Urban-rural and gender differences in tobacco and alcohol use, diet and physical activity among young black South Africans between 1998 and 2003. *Glob. Health Action* 6, 19216.
- R Core Team, 2015. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing (2014, Available at: www.R-project.org).
- Rodiek, S., 2002. Influence of an outdoor garden on mood and stress in older persons. *J. Ther. Hortic.* 13, 13–21.
- Seto, K.C., Güneralp, B., Hutyra, L.R., 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl. Acad. Sci. U. S. A.* 109, 16083–16088.
- Sodjinou, R., Agueh, V., Fayomi, B., Delisle, H., 2008. Obesity and cardio-metabolic risk factors in urban adults of Benin: relationship with socio-economic status, urbanisation, and lifestyle patterns. *BMC Public Health* 8, 84.
- Soga, M., Gaston, K.J., 2016. Extinction of experience: the loss of human-nature interactions. *Front. Ecol. Environ.* 14, 94–101.
- Soga, M., Yamaura, Y., Aikoh, T., Shoji, Y., Kubo, T., Gaston, K.J., 2015. Reducing the extinction of experience: association between urban form and recreational use of public greenspace. *Landsc. Urban Plan.* 143, 69–75.
- Soga, M., Gaston, K.J., Koyanagi, T.F., Kurisu, K., Hanaki, K., 2016. Urban residents' perceptions of neighbourhood nature: does the extinction of experience matter? *Biol. Conserv.* 203, 143–150.
- Sommerfeld, A.J., Waliczek, T.M., Zajicek, J.M., 2010. Growing minds: evaluating the effect of gardening on quality of life and physical activity level of older adults. *HortTechnology* 20, 705–710.
- Statista, 2015. Number of gardeners in the USA. Available at: www.statista.com/statistics/227419/number-of-gardeners-usa (Accessed December 11, 2015).
- Statistics Bureau, Ministry of Internal Affairs and Communications, 2011. *Shakai seikatsu kihon chosa*. Available at: www.e-stat.go.jp/SG1/toukeidb/GH07010101Forward.do;jsessionid=6Jy2WtfQFTTt2bW2pQyMFp8L1hTjnpngmZnDGZjrsrywpcRG829!1540013709!30969698 (Accessed December 11, 2015).
- Stott, I., Soga, M., Inger, R., Gaston, K.J., 2015. Land sparing is crucial for urban ecosystem services. *Front. Ecol. Environ.* 13, 387–393.
- Takano, T., Nakamura, K., Watanabe, M., 2002. Urban residential environments and senior citizens longevity in megacity areas: the importance of walkable green spaces. *J. Epidemiol. Community Health* 56, 913–918.
- Tzoulas, K., Korpela, K., Venn, S., et al., 2007. Promoting ecosystem and human health in urban areas using green infrastructure: a literature review. *Landsc. Urban Plan.* 81, 167–178.
- van den Berg, A.E., Custers, M.H., 2011. Gardening promotes neuroendocrine and affective restoration from stress. *J. Health Psychol.* 16, 3–11.
- van den Berg, A.E., van Winsum-Westra, M., de Vries, S., van Dillen, S.M., 2010. Allotment gardening and health: a comparative survey among allotment gardeners and their neighbors without an allotment. *Environ. Health* 9, 74.
- Viechtbauer, W., 2010. Conducting meta-analyses in R with the metafor package. *J. Stat. Softw.* 36, 1–48.
- Wakefield, S., Yeudall, F., Taron, C., Reynolds, J., Skinner, A., 2007. Growing urban health: community gardening in South-East Toronto. *Health Promot. Int.* 22, 92–101.
- Waliczek, T.M., Zajicek, J.M., Lineberger, R.D., 2005. The influence of gardening activities on consumer perceptions of life satisfaction. *Hortscience* 40, 1360–1365.
- Wang, D., MacMillan, T., 2013. The benefits of gardening for older adults: a systematic review of the literature. *Act. Adapt. Aging* 37, 153–181.
- Wichrowski, M., Whiteson, J., Haas, F., Mola, A., Rey, M.J., 2005. Effects of horticultural therapy on mood and heart rate in patients participating in an inpatient cardiopulmonary rehabilitation program. *J. Cardiopulm. Rehabil. Prev.* 25, 270–274.
- Wilson, J.F., Christensen, K.M., 2011. The relationship between gardening and depression among individuals with disabilities. *J. Ther. Hortic.* 21, 28–41.
- Wood, C.J., Pretty, J., Griffin, M., 2016. A case-control study of the health and well-being benefits of allotment gardening. *J. Public Health* 38, e336–e344.
- World Health Organization (WHO), 1948. *Constitution of the World Health Organization: Basic Document*. WHO, Geneva, Switzerland.
- World Health Organization (WHO), 2016. *Depression*. Available at: www.who.int/mediacentre/factsheets/fs369/en (Accessed June 11, 2016).
- Zick, C.D., Smith, K.R., Kowaleski-Jones, L., Uno, C., Merrill, B.J., 2013. Harvesting more than vegetables: the potential weight control benefits of community gardening. *Am. J. Public Health* 103, 1110–1115.